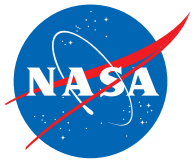

Jet Propulsion Laboratory
California Institute of Technology

Uncertainties in modeling the Antarctic Ice Sheet contribution to sea level rise:

An exploration of Model Response to Errors in Climate Forcing, Boundary Conditions, and Internal Parameters

01/10/2018

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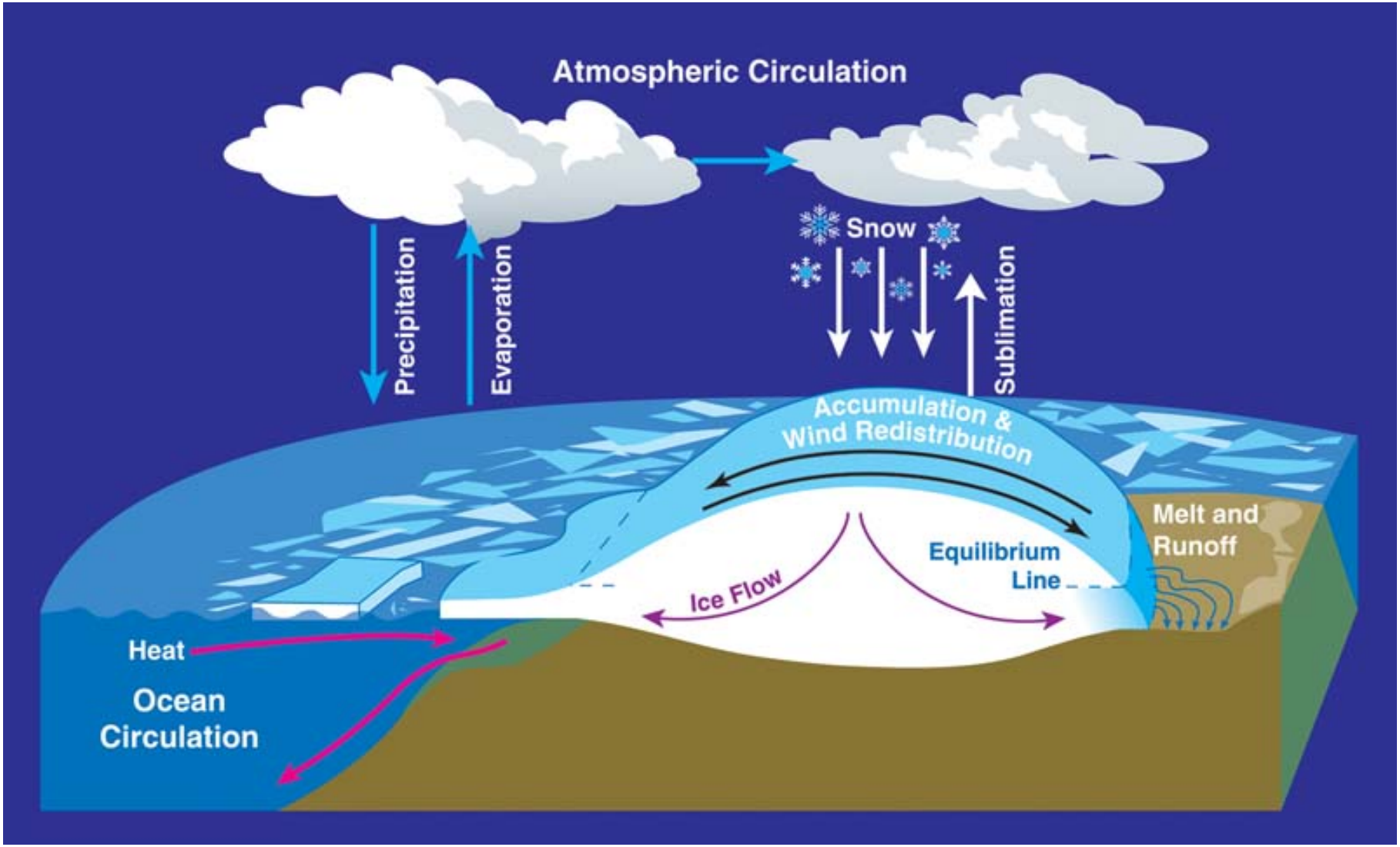
We use the
Ice Sheet System Model (ISSM)
to model ice flow, ice thermal properties, and migration of floating ice grounding lines

and

the ISSM-DAKOTA framework
for uncertainty quantification analyses

ISSM models the physics of ice flow and its response to changes in forcing and ice properties

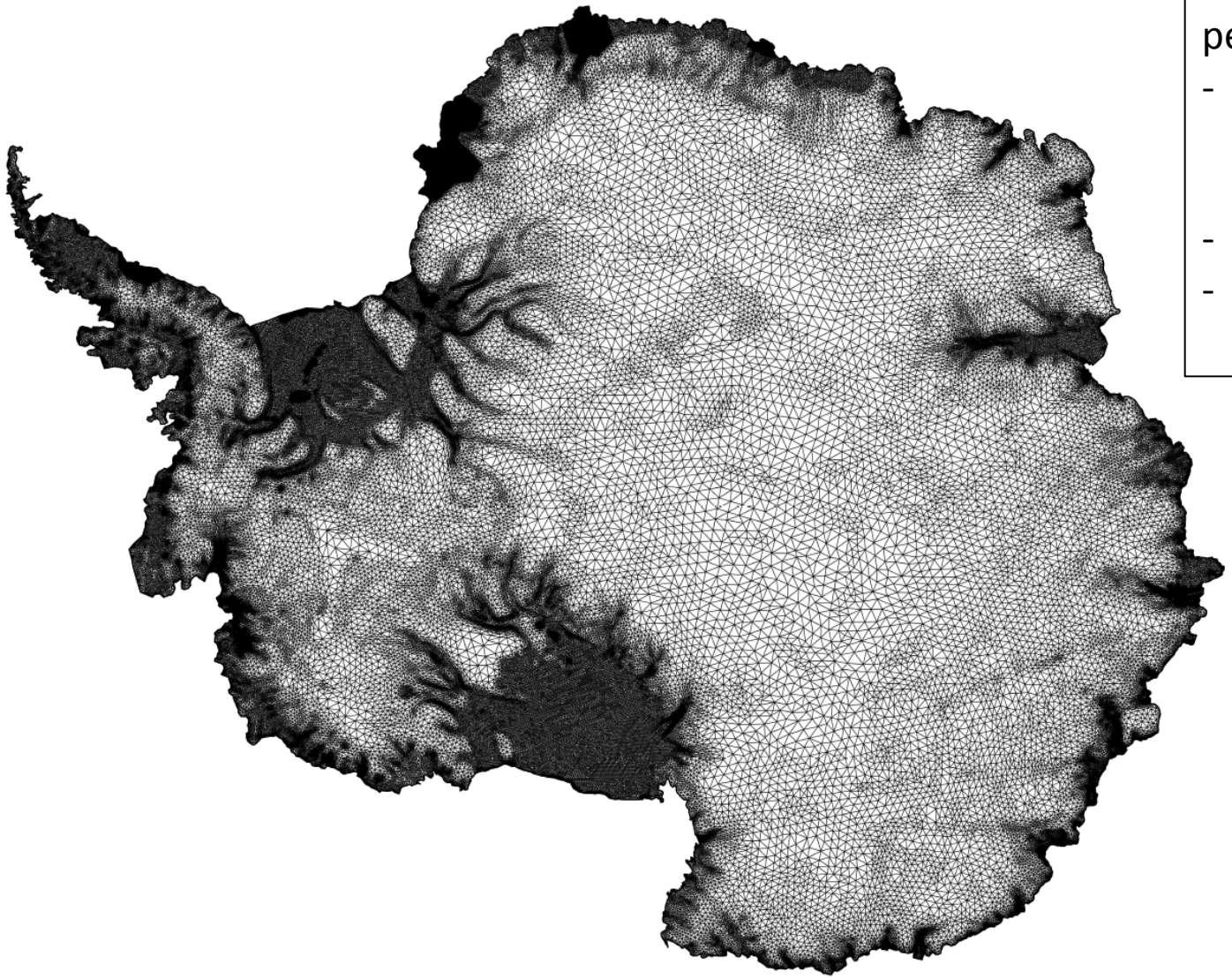


(Credit: NASA)

Ice Flow Model:

ISSM Antarctica

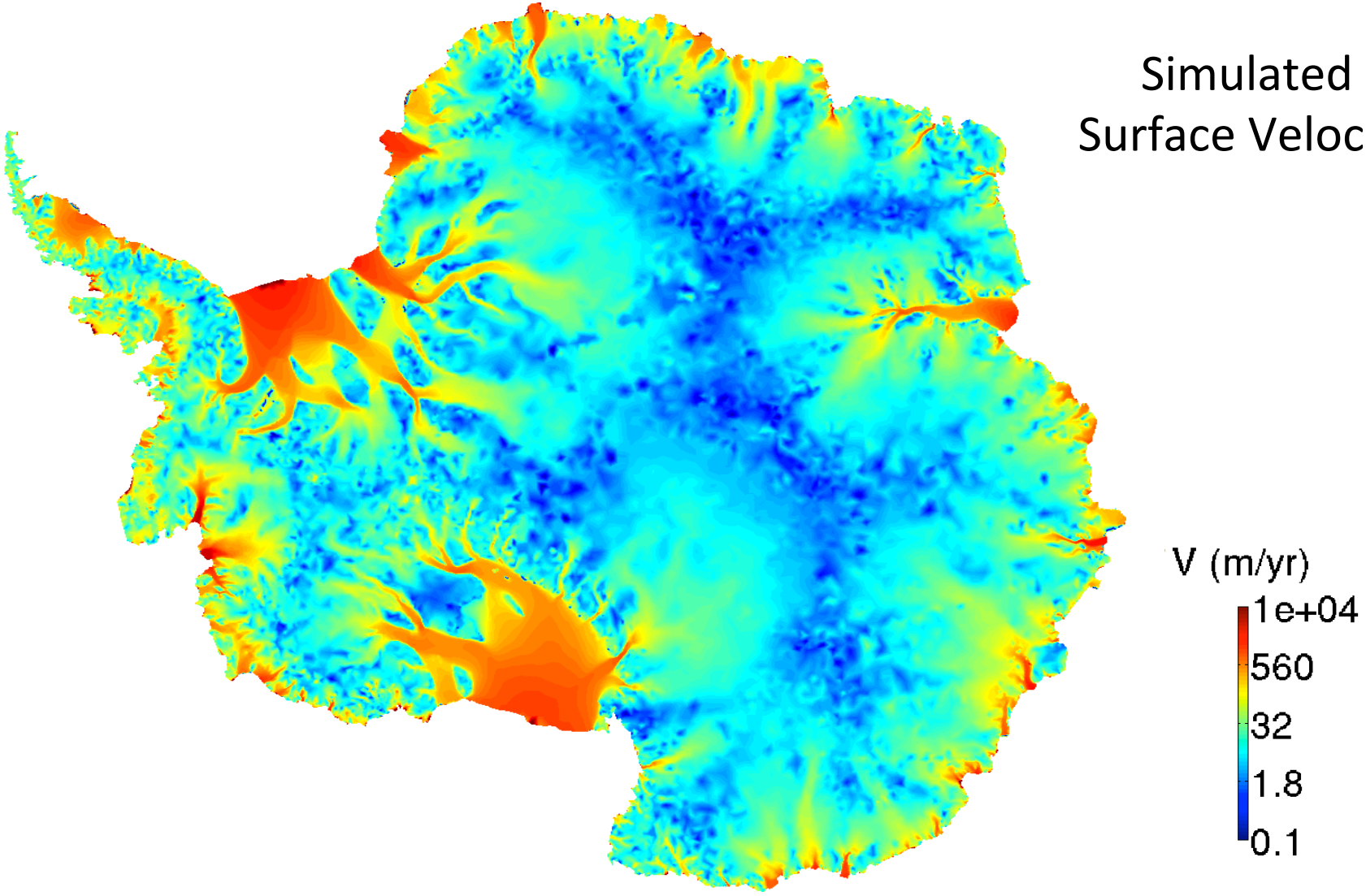
JPL-UCI Ice Sheet System Model (ISSM) Antarctica uses a finite element, anisotropic triangular mesh



187,447 finite elements per layer:

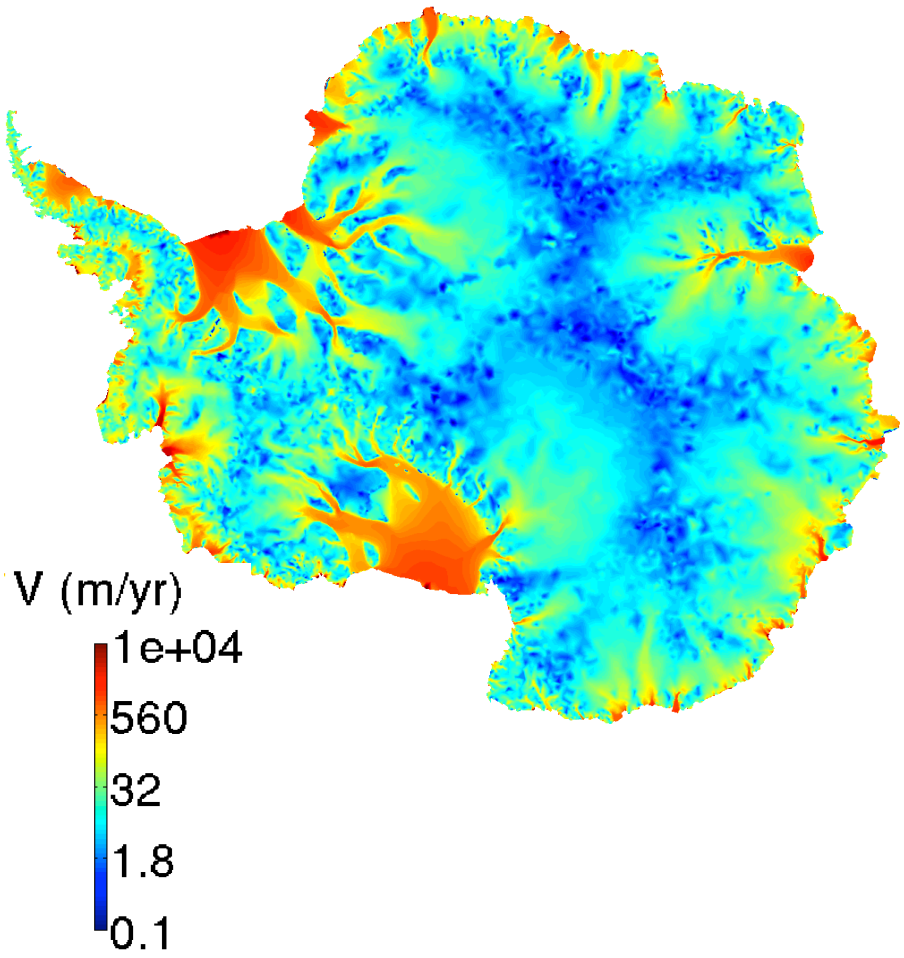
- 1 km resolution along the coast and at shear margins
- 50 km at the divides
- At least 8km on floating ice

Higher spatial resolution is used where we have strong shear and for floating ice

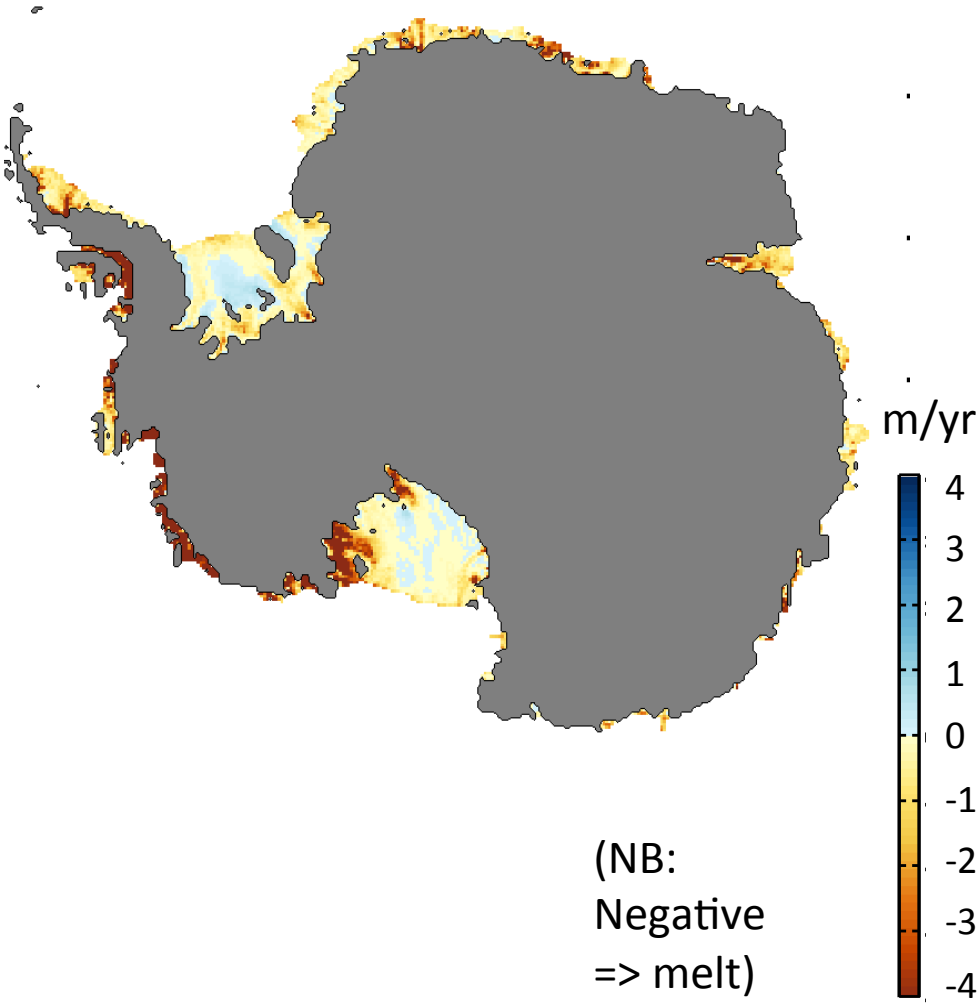


A large portion of the ice sheet is floating, and is affected by ocean (and atmospheric) forcing

Surface Velocity



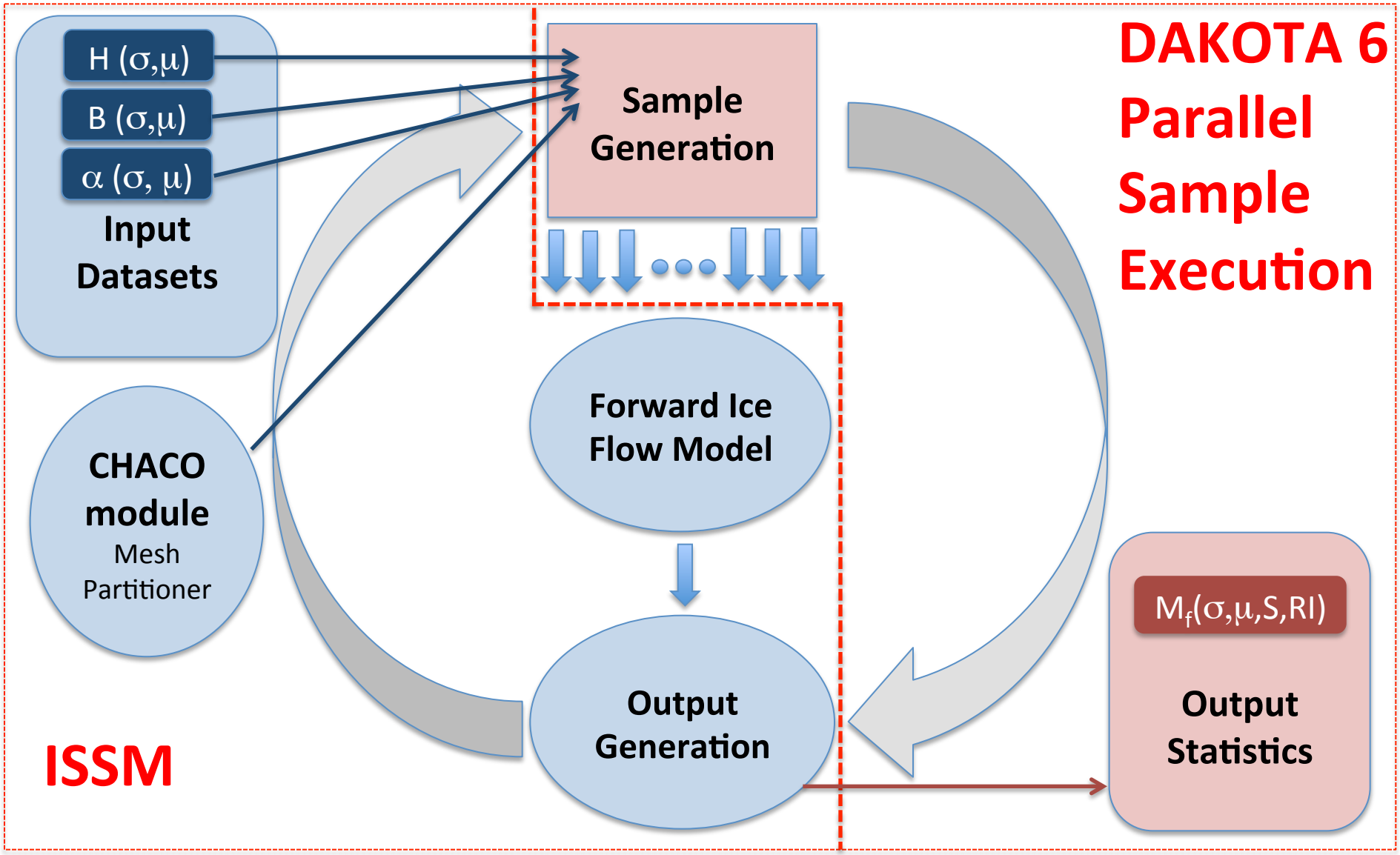
Ice Shelf Basal Melt



Uncertainty Quantification Techniques:

ISSM-DAKOTA FRAMEWORK

Design Analysis Kit for Optimization and Terascale Applications (DAKOTA) software is embedded into ISSM



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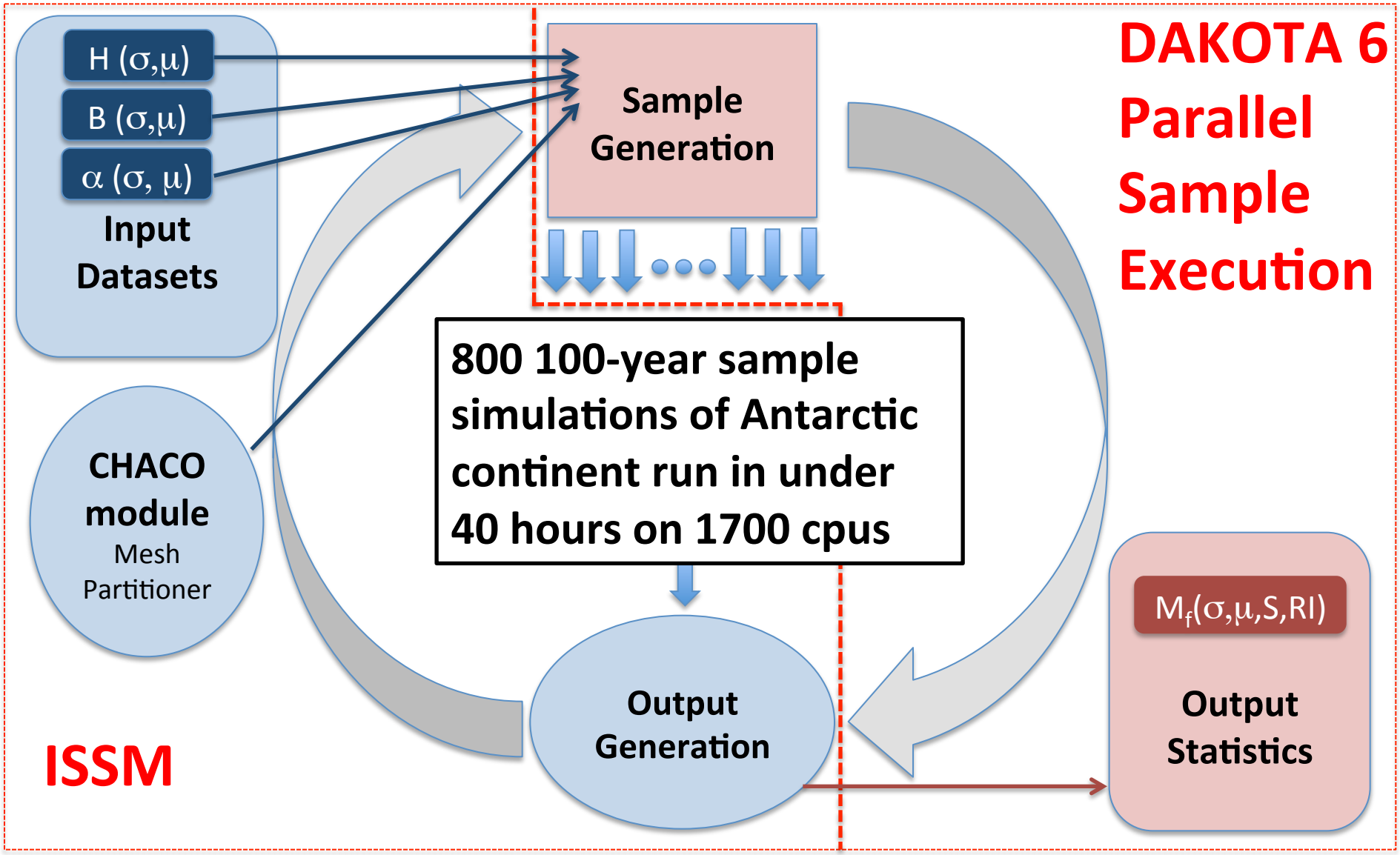


Continental-Scale Utility of

SAMPLING ANALYSIS

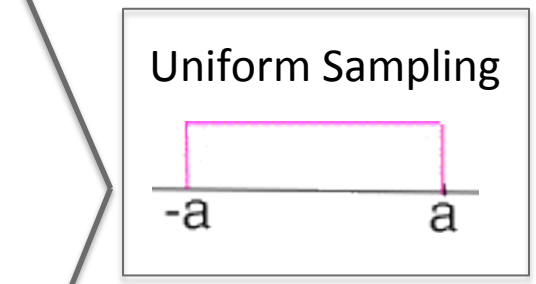
What is the uncertainty of projected extreme changes in regional ice flow (mass flux) and Sea Level Equivalent (SLE) contribution from Antarctica?

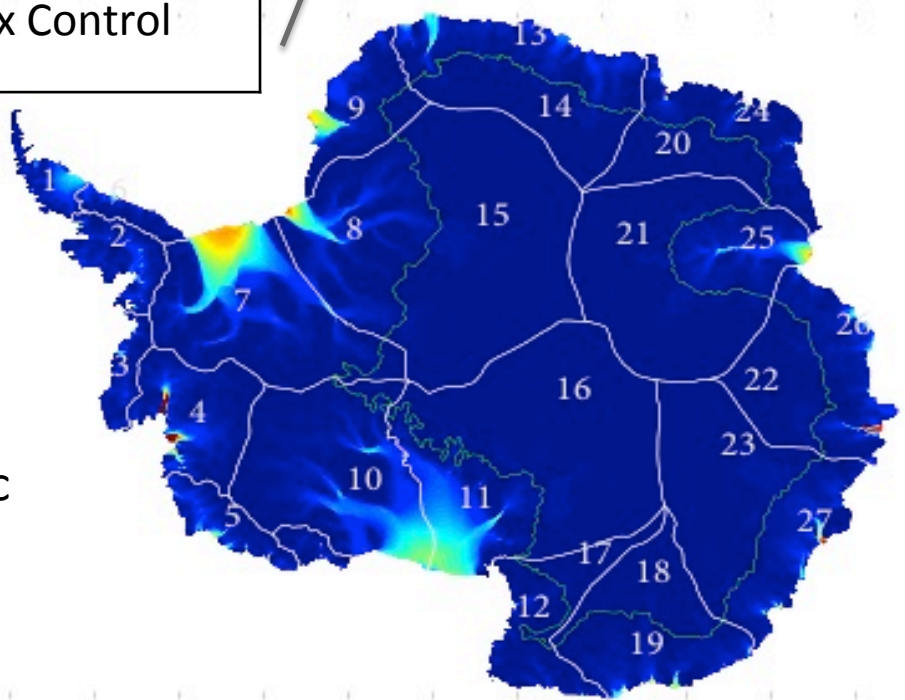
FORCING:

- 100-year forward run forced with atmospheric boundary conditions from RACMO2 (mean annual 1979-2010).
- Ice shelve melt rates: from mean annual ECCO2-MITgcm 150-layer 9 km (2004-2013)

We sample four variables in Antarctica with extreme values, using uniform sampling over 27 geographically-based partitions for 100 year period

Parameter/Forcing	Min	Max
Ice Shelf Melt	Minimum annual melt rates (ECCO2-MITgcm)	10 x Mean annual melt rates
Basal Drag	40% of Control	Control value
Ice Viscosity	60% of Control	Control value
Accumulation	50% of Control	2 x Control





27 Geographic Partitions

We sample four variables in Antarctica with extreme values, using uniform sampling over 27 geographically-based partitions for 100 year period

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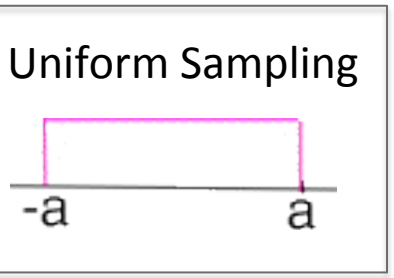
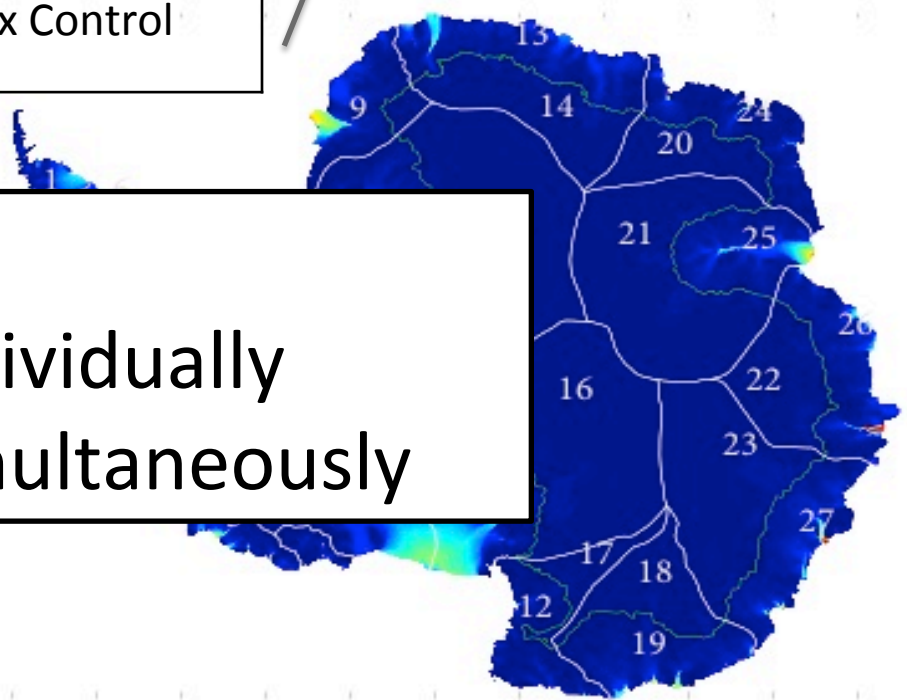


STRATEGY

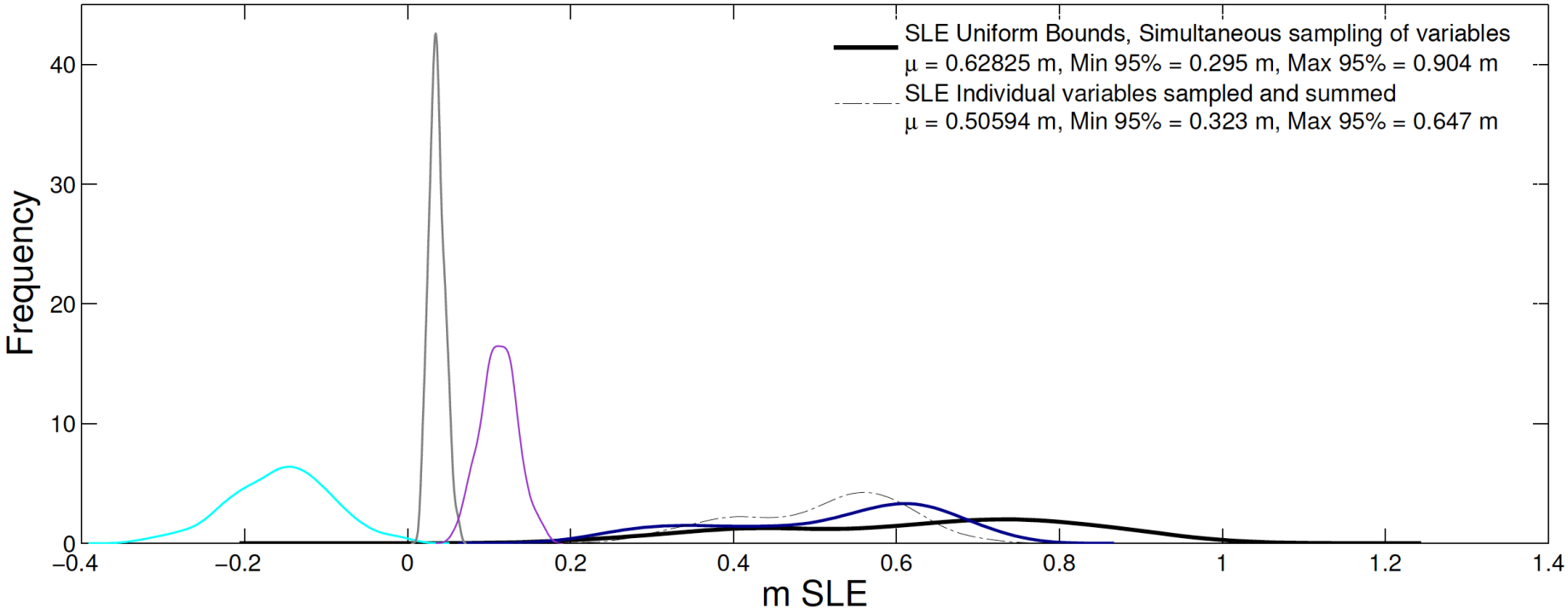
⇒Sample variables Individually

⇒Sample variables simultaneously



Partitions

Sampling of individual variables independently highlights that ice shelf melt is a dominant contributor to sea level



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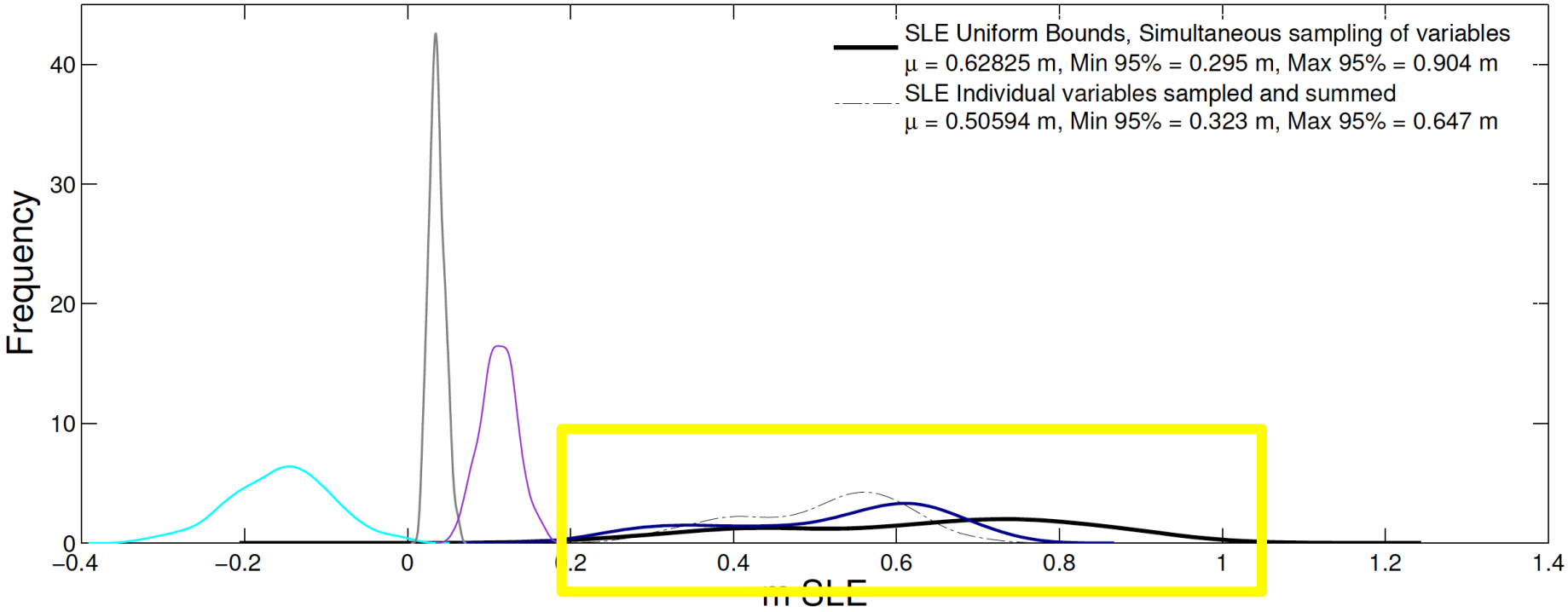

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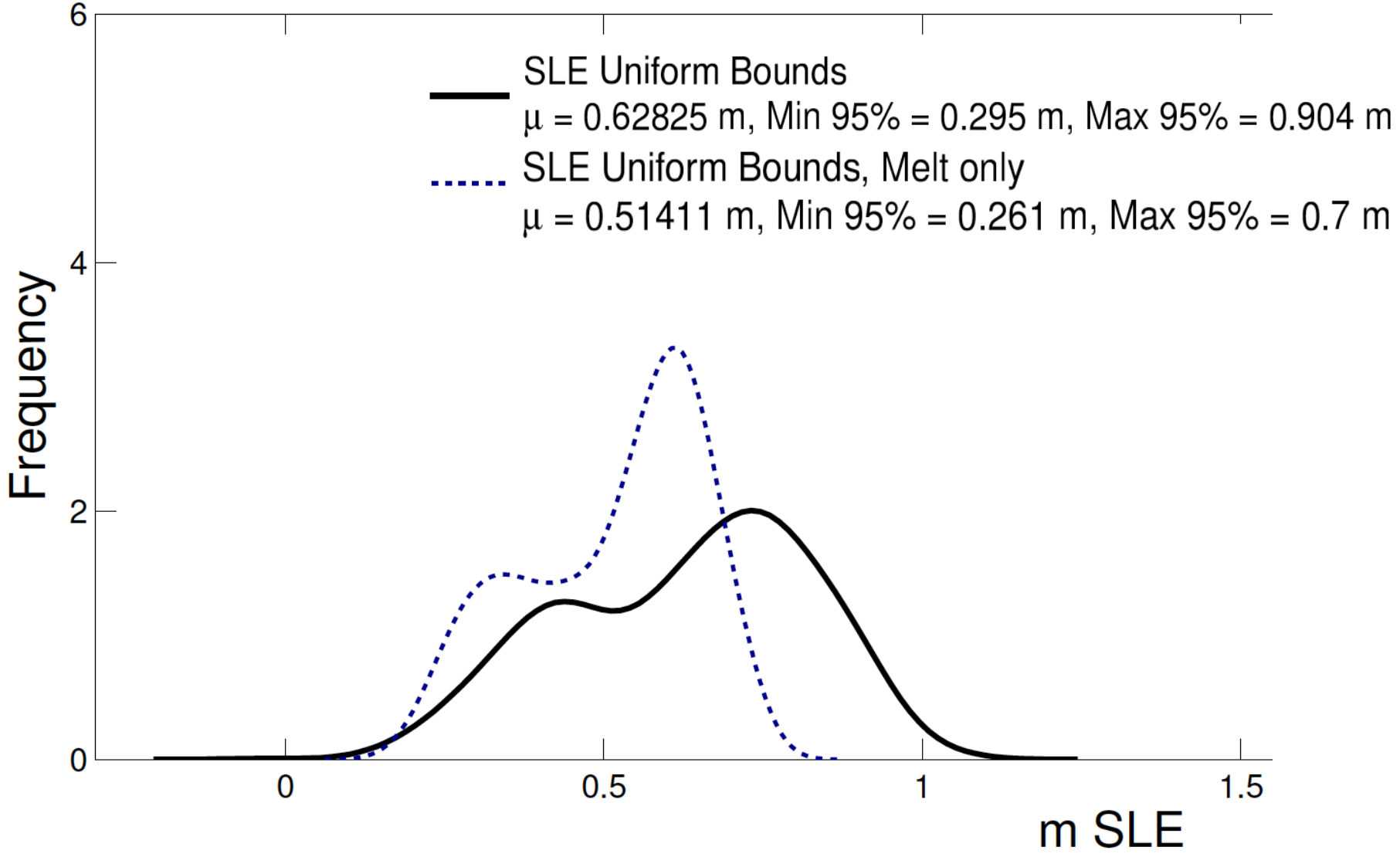
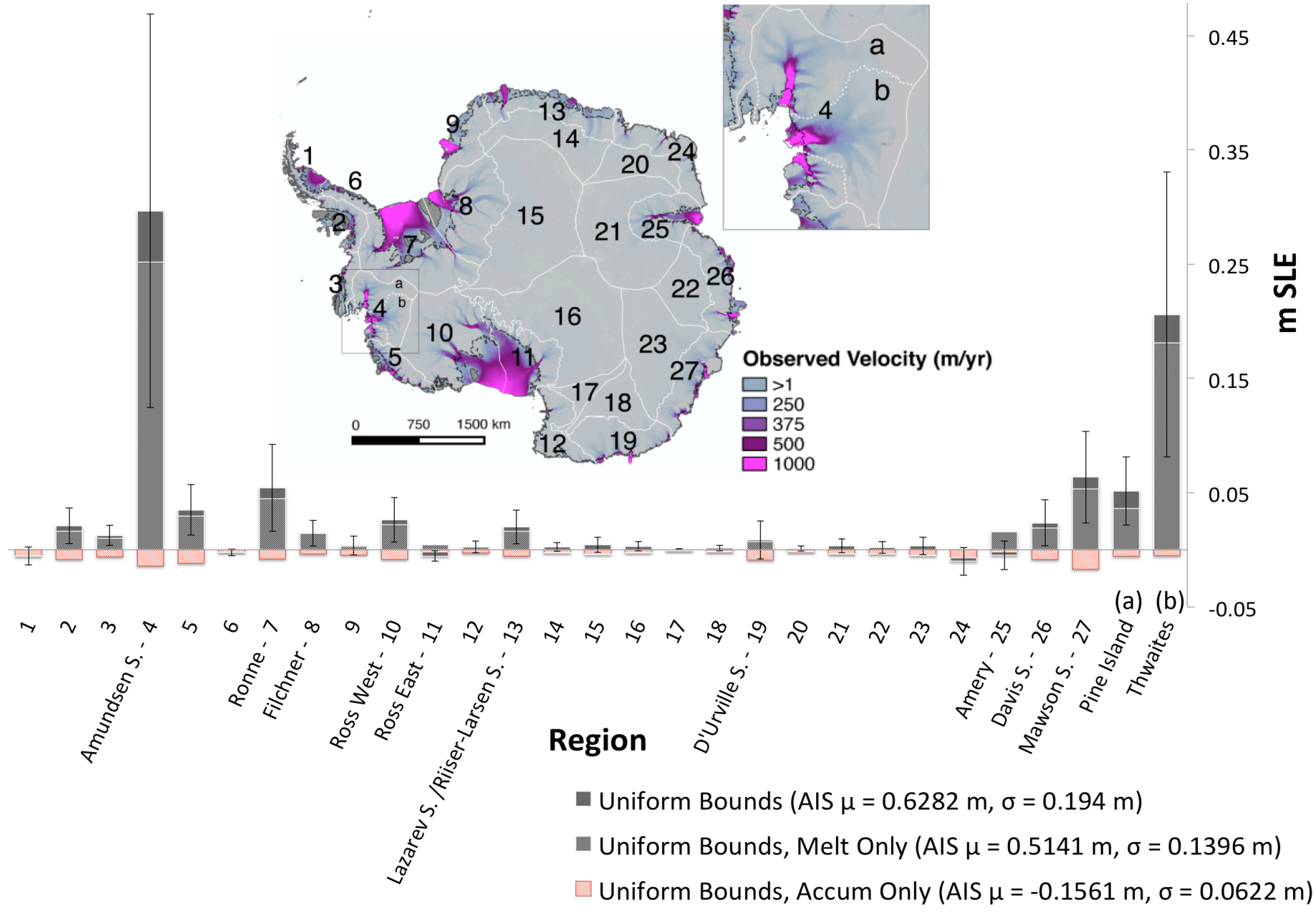
Ice Shelf Melt is responsible for a majority of the spread, and for the bimodal distribution



Regional Analysis:

UNCERTAINTY IN SEA LEVEL CONTRIBUTION

Regional analysis reveals that ice shelf melt rates for one outlet are largely responsible for uncertainty in ISSM 100-year sea level contribution



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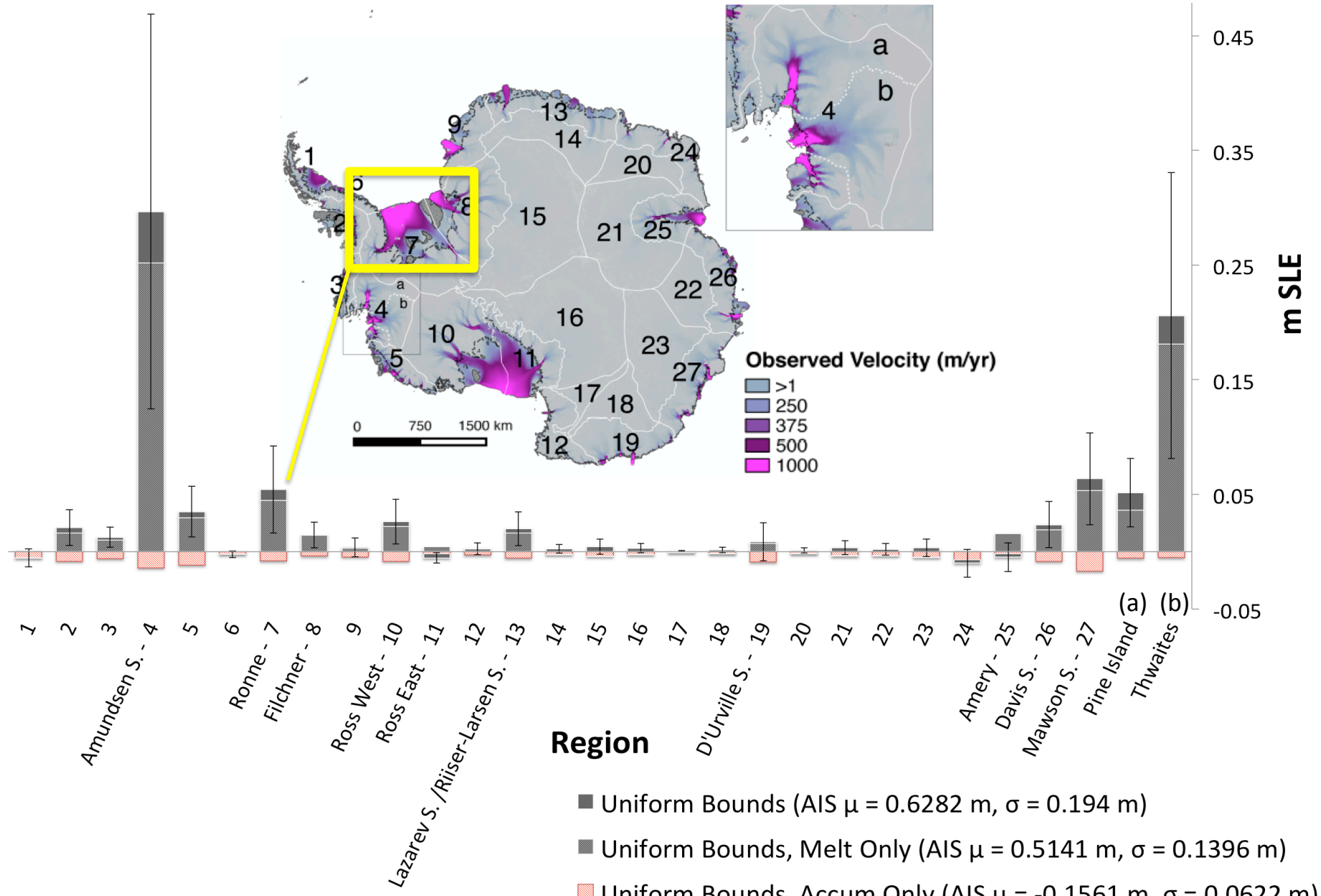

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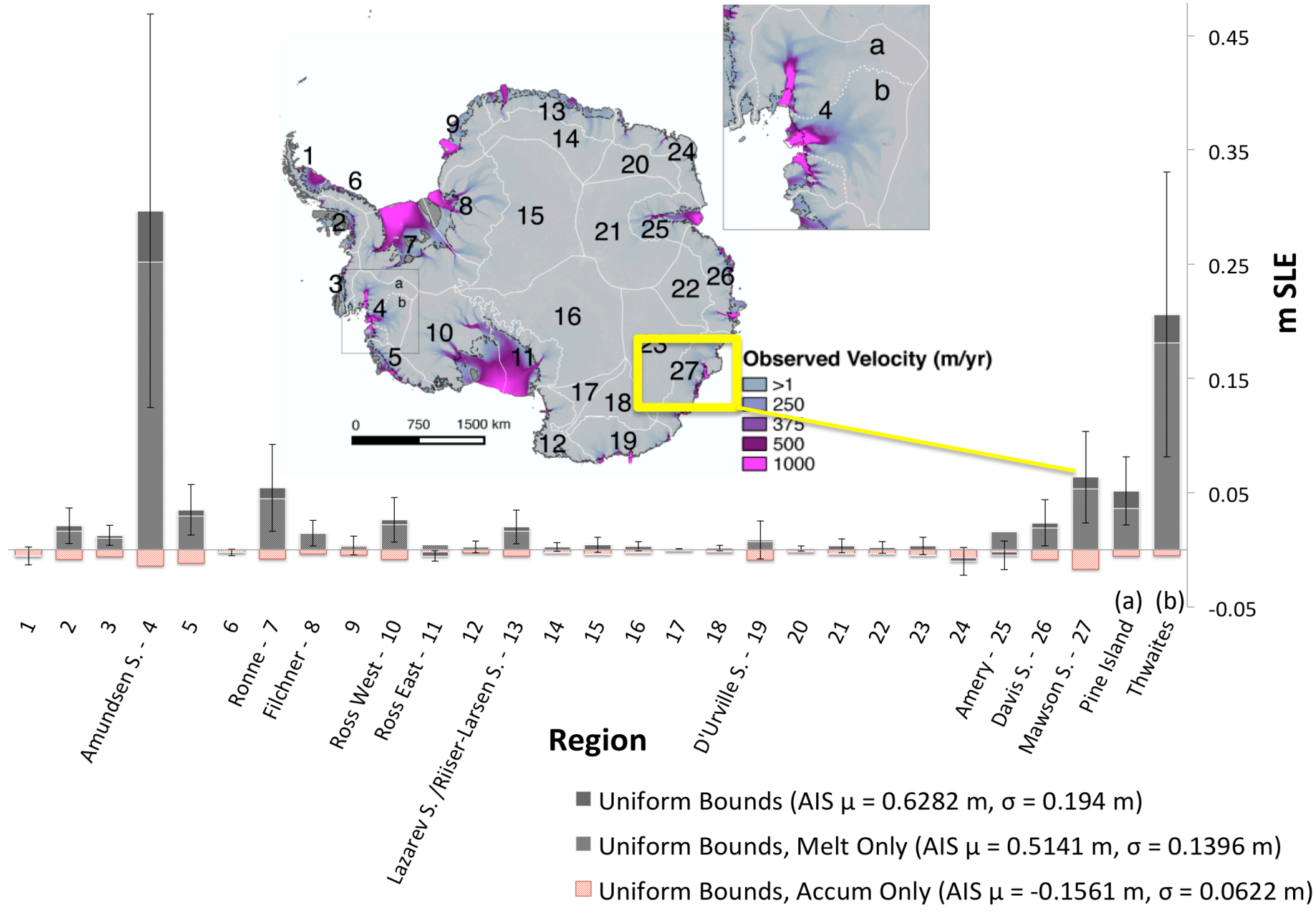

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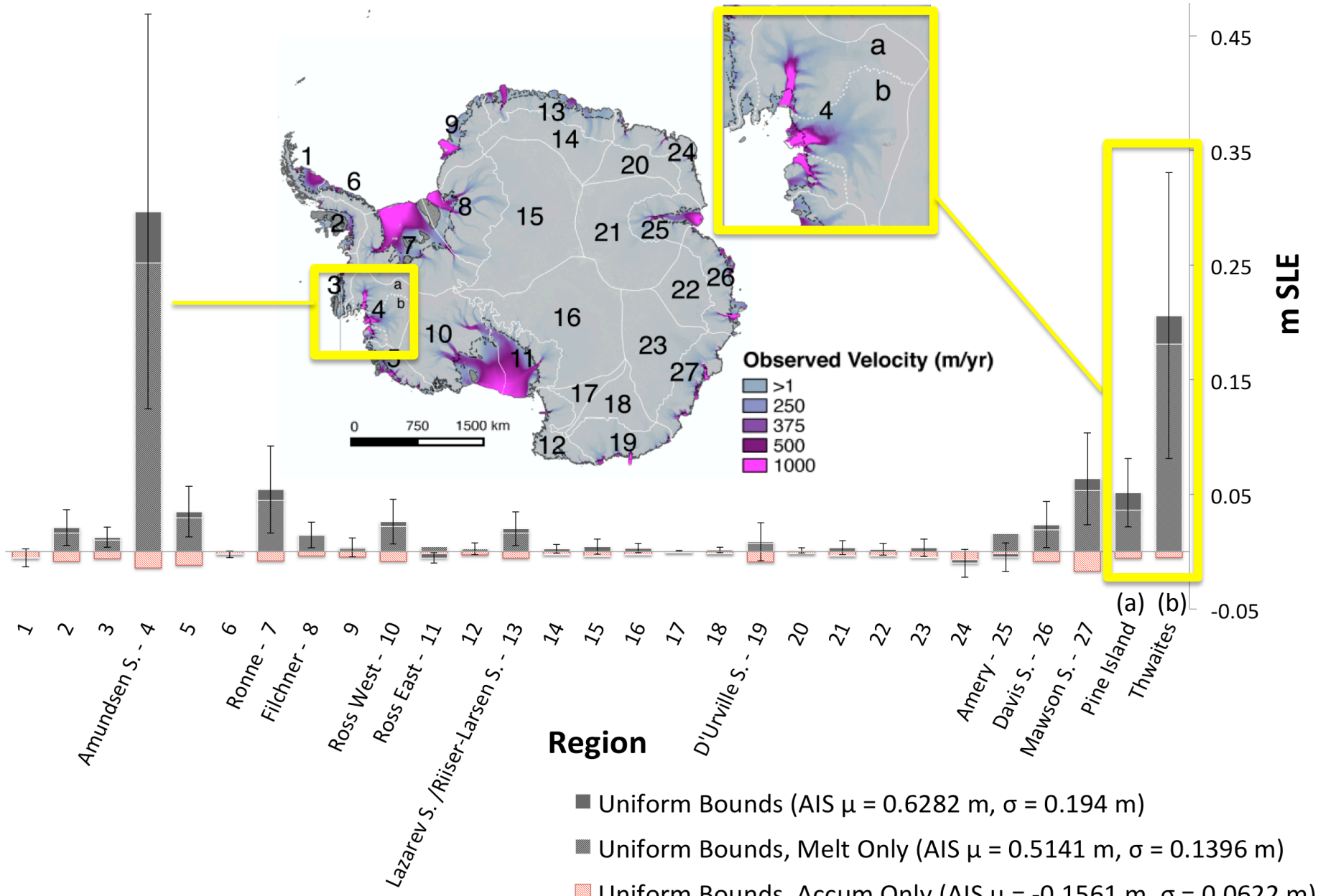
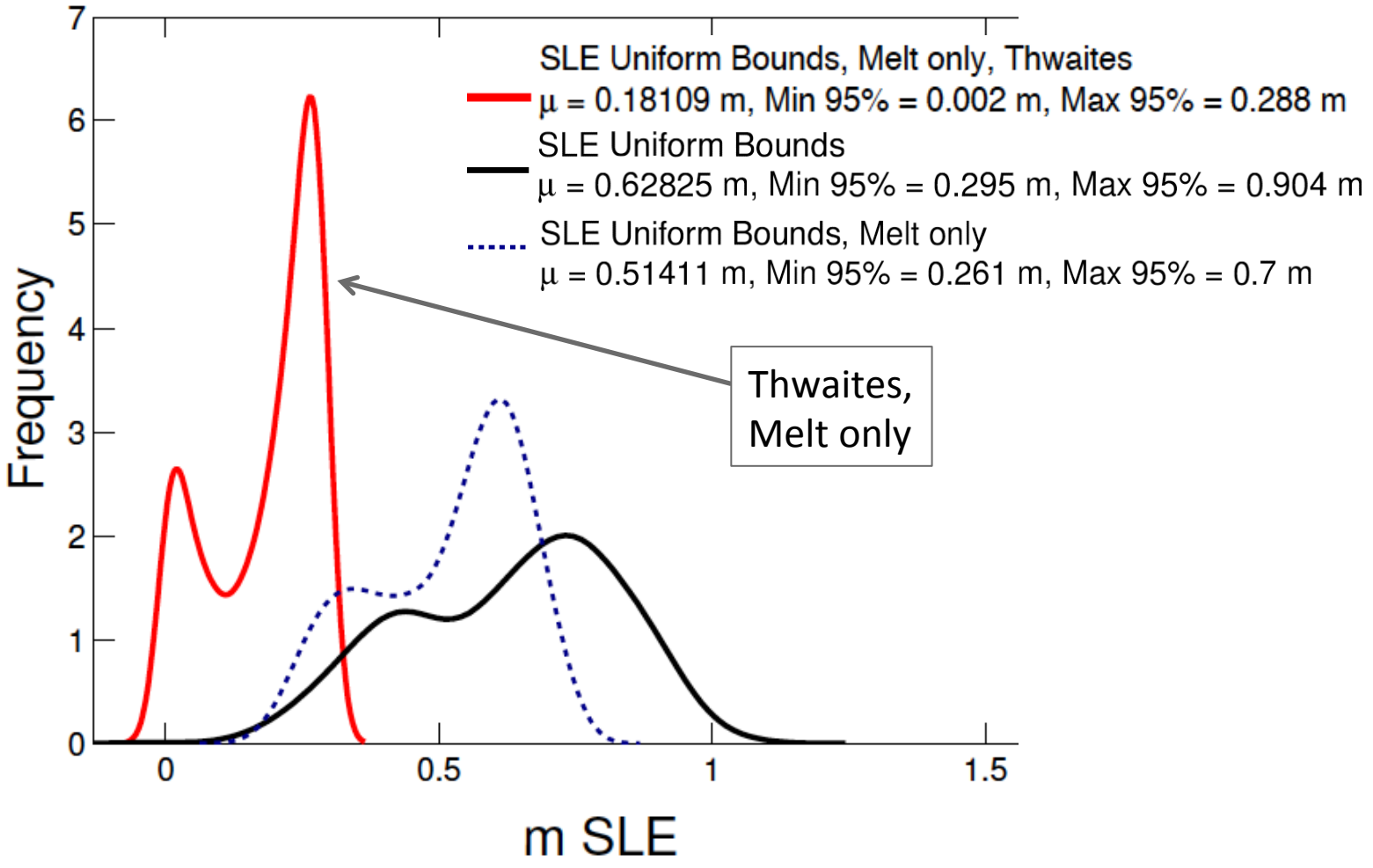


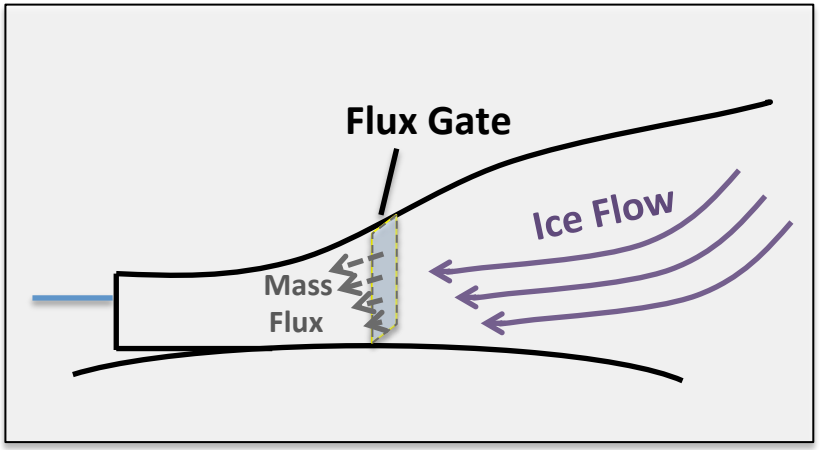
The response to ice shelf melt rates in Thwaites accounts for a majority of the uncertainty and bimodal behavior of the continental ice sheet SLE signal

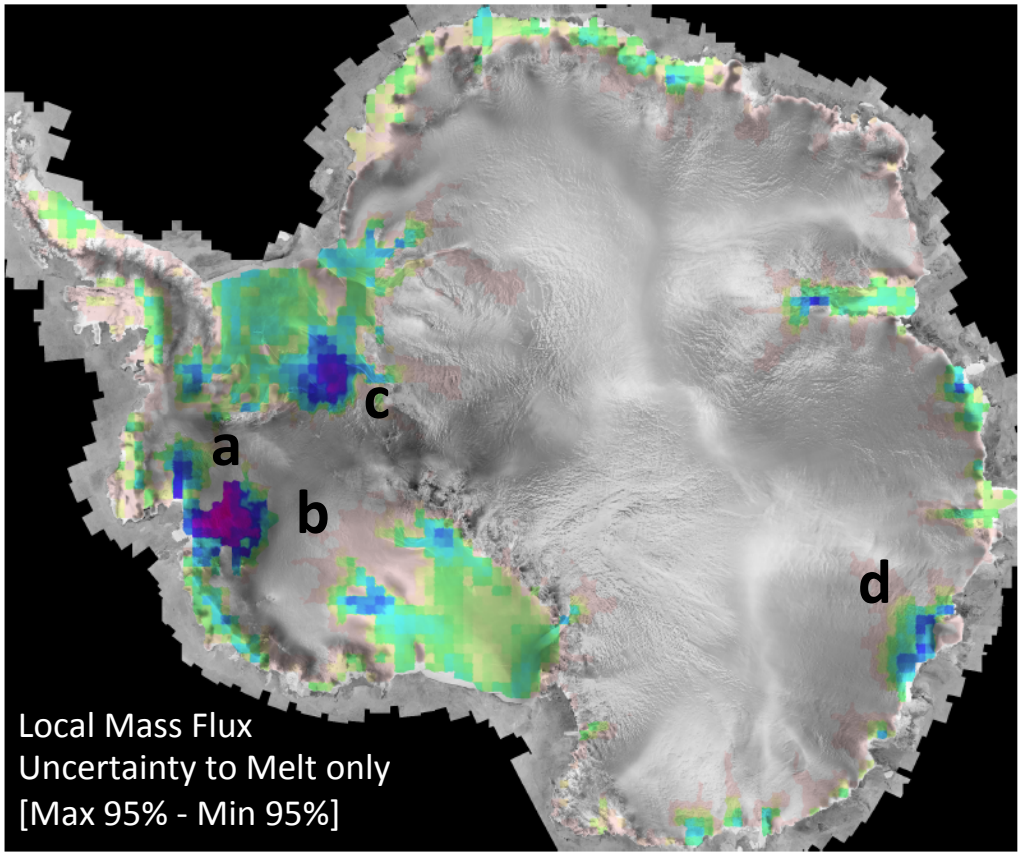


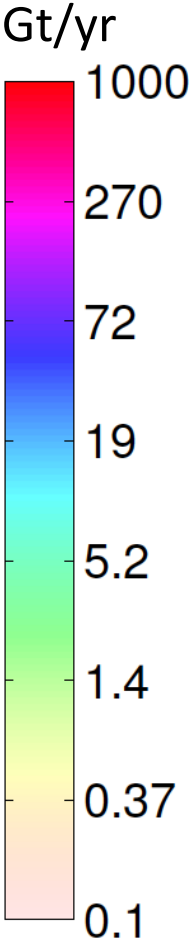
Regional Analysis:

UNCERTAINTY IN MASS FLUX

Uncertainty in mass flux is indicative of ice flow dynamic sensitivity/feedback to ice shelf melt rates in areas with largest SLE contribution

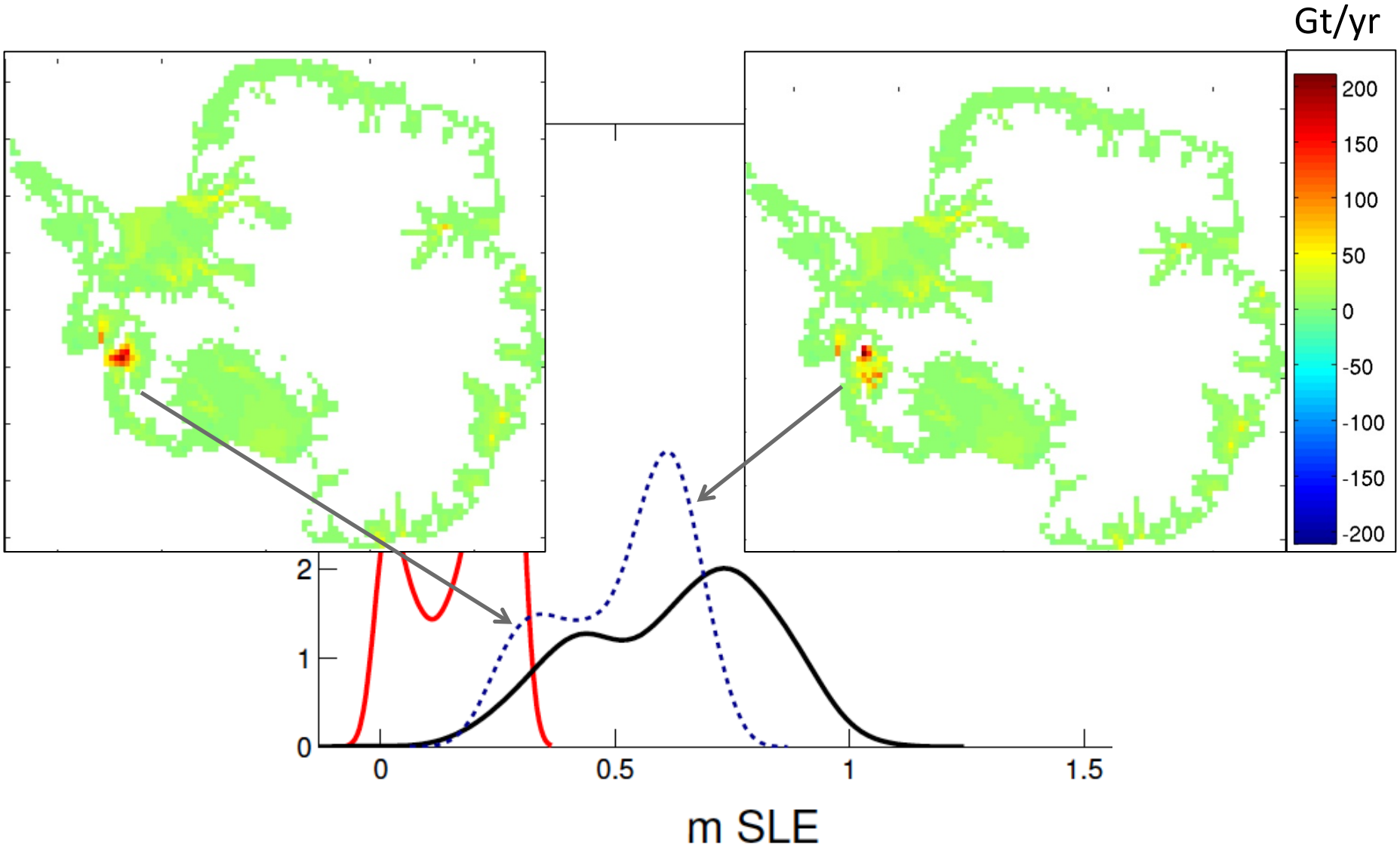




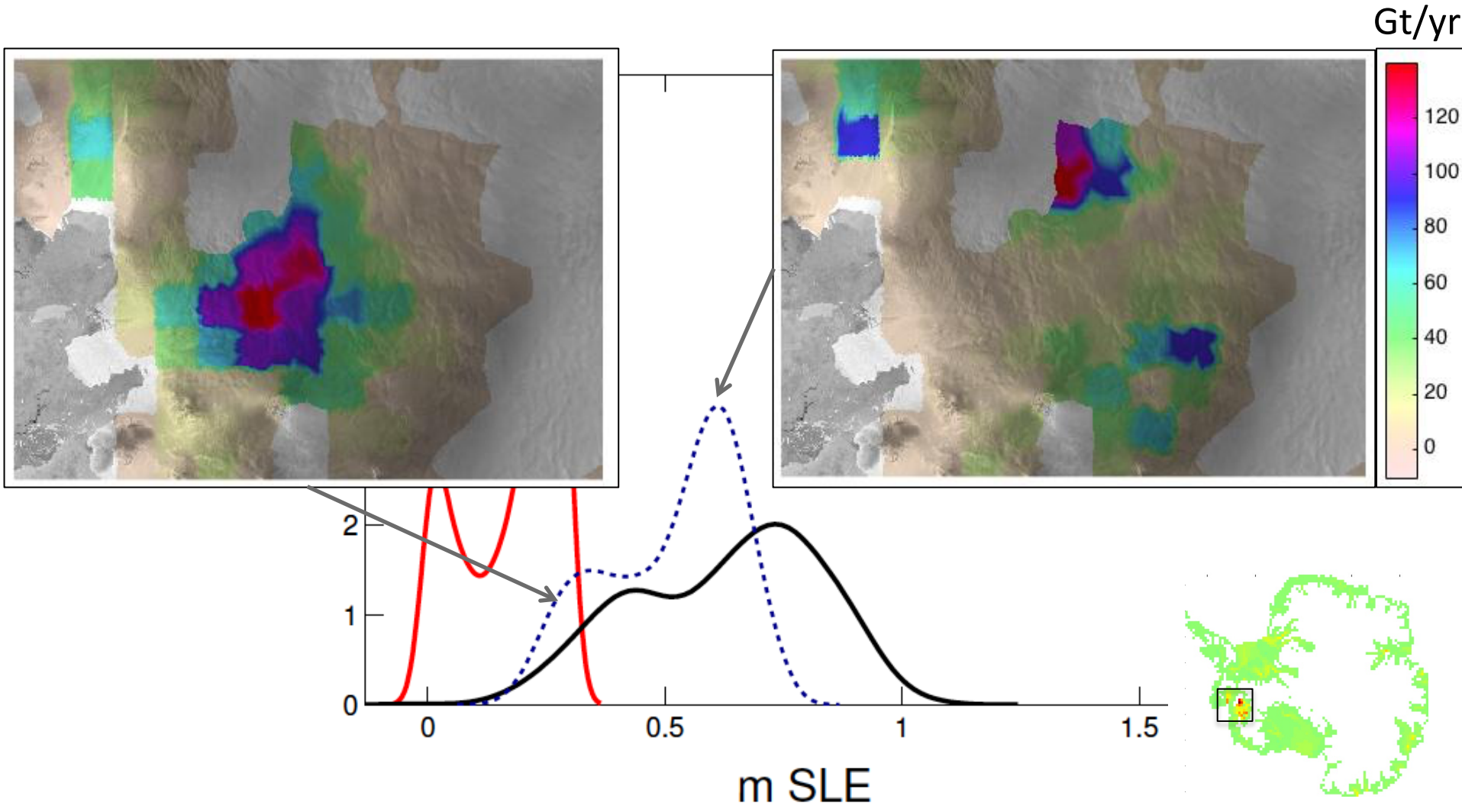


a - Pine Island
b - Thwaites
c - Ronne Ice Shelf (Moller/Institute)
d - Mawson Sea (Totten/Moscow U.)

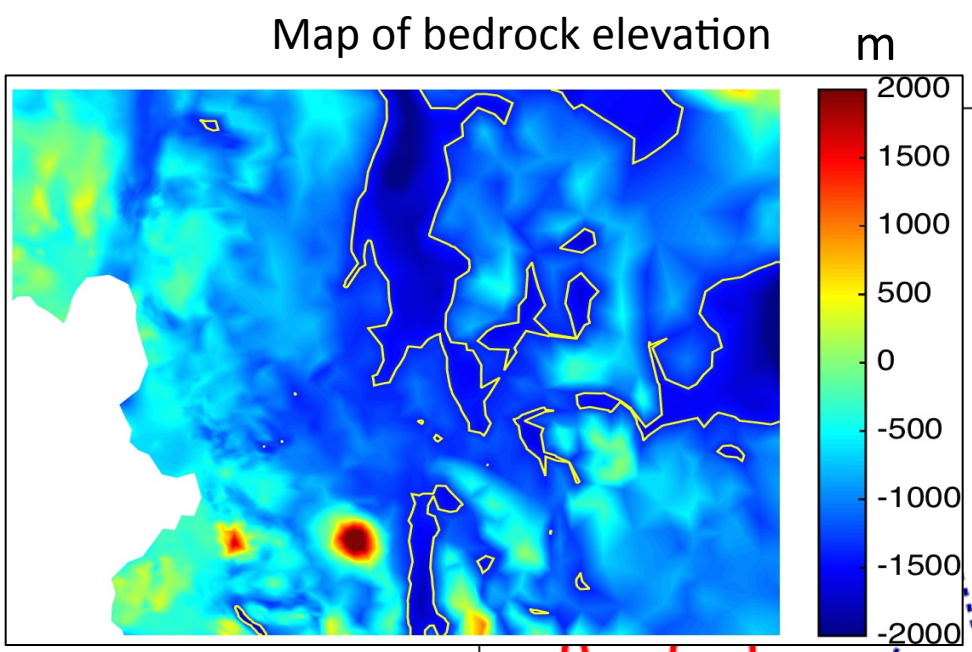
We can plot separately the mean mass flux of the left and right hump of the distribution for comparison

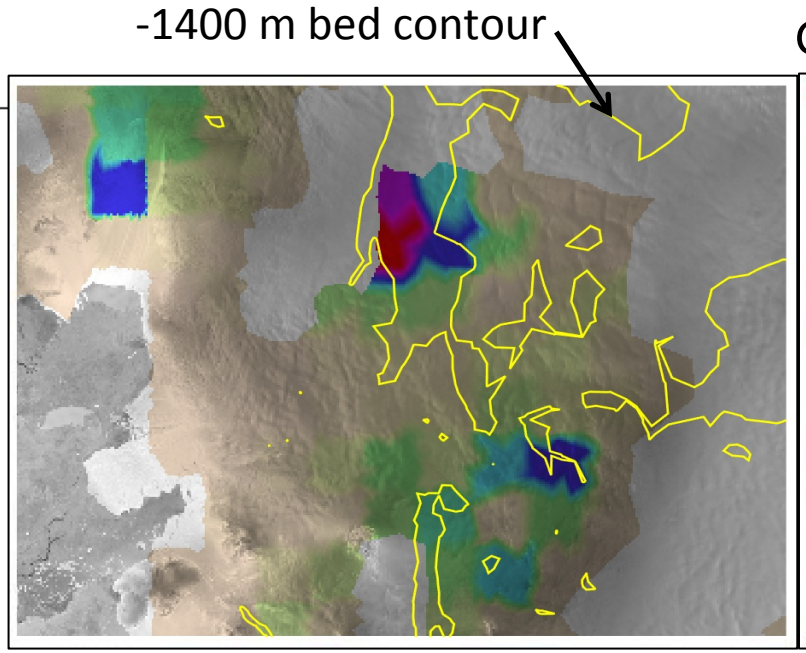


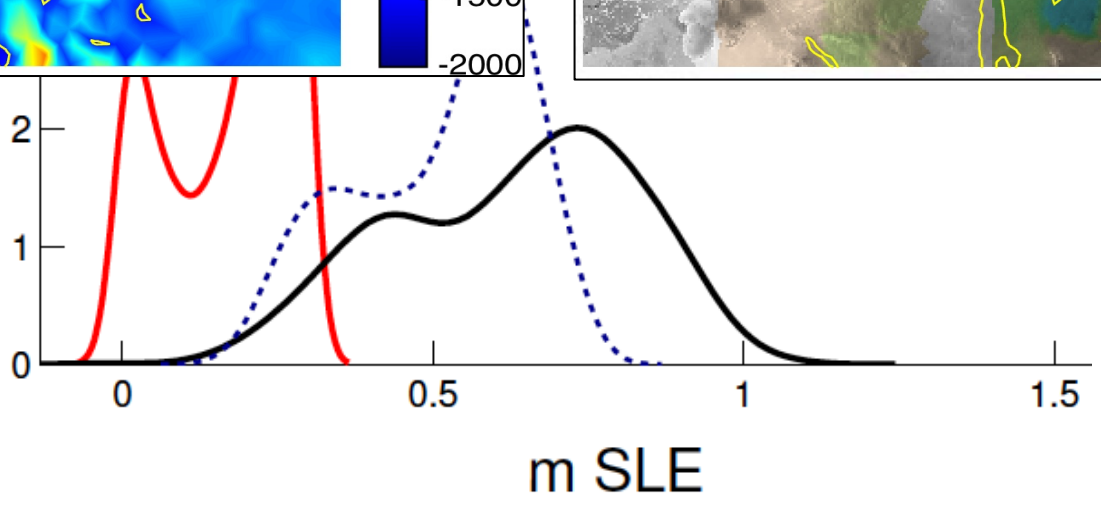
The Thwaites right hump indicates a mean retreat that is > 100km upstream from the mean retreat of left hump

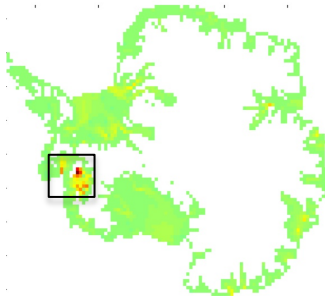


In the right hump, the ice front has retreated into the interior, deeper channels of the basin









Conclusions

We use uncertainty analyses to investigate how a continental ice sheet model of the Antarctic ice sheet responds to changes in forcing and boundary conditions.

- Uncertainty Quantification analysis can help us improve understanding of ice sheet model sensitivity to input error and uncertainties in projections

- Sampling analysis allows us to quantify how results vary within a parameter space
  - ➢ Antarctica Example
    - We investigate how variables affect model SLE uncertainty, including:
      - Melt, accumulation, basal drag, and ice viscosity
    - We focus on experiments forced with extreme bounds: designed to encompass a large range of scenarios, push the model within physically plausible end member scenarios, and isolate thresholds
    - For comparison, future experiments will include setting "informed" bounds regionally, to produce a more realistic ensemble of scenarios

  - ✓ Ice shelf melt rate is a key contributor to SLE uncertainty.
  - ✓ Sources of uncertainty vary regionally; Regional analysis suggests that Thwaites glacier, Ronne Ice Shelf, and the Mawson Sea Sector are areas on which to focus in the future, in terms of observational and modeling efforts.

Thank you!